# AN ECOLOGICAL STUDY OF THE QUEEN SNAKE, *REGINA SEPTEMVITTATA* (SAY) IN KENTUCKY

BRANLEY A. BRANSON AND EDD C. BAKER
*Eastern Kentucky University, Richmond, Kentucky 40475*

ABSTRACT

The bulk of Kentucky queen snakes' diet (93.2%) consists of softshelled *Orconectes juvenilis*; the remainder is occasional fishes, tadpoles and other genera of crayfish. Food habits varied little between areas and between different times of the year. The snake is an opportunistic feeder, preying upon the most abundant crayfish in its habitat, taking prey by ambush.

The observed sex ratio, both in adults and newborn, was 1:1. Females generally do not reproduce until their third year, but immature eggs may be found during the second year in the ovaries, possibly being produced late in the fall of the first year. The minimum size of a mature female was 344 mm total length. Males become sexually mature during their second year. Mating probably occurs both in spring and fall, with young females mating for the first time during the second fall of life or the spring of the third year. Female snakes contained from 7 to 49 immature eggs in addition to mature eggs or embryos, representing the reproductive potential for the following season. This indicates an annual reproductive season rather than a biannual one. The total egg count increases proportionally with body size. Being viviparous, the retained eggs lack shells at all stages of development. The thin chorionic membrane of oviducal eggs lies in intimate contact with the maternal tissues during development. A notable increase in egg size during this time indicates transmission of dissolved nutrients. The number of young per litter varies between 8 to 17, averaging 12.8 per female. A discussion of the process of birth is presented. All newborn snakes shed their fetal, very thin, skin within 24 hours of parturition, and a thicker skin is shed four days later.

Growth rates were highest during the first year, yearlings showing an average increase of 75% length increase over newborn. The percentage increase for the second year class averaged 44.8. The total growth for specimens older than two years, regardless of age, was 14 to 15%.

Cloacal temperatures were higher by as much as 6.2° C than ambient ones, indicating a tendency toward temperature regulation. The mean cloacal temperature for all specimens was 25.6° C. The critical thermal maxima for adult queen snakes varied from 43.4° C to 44.5° C (mean, 43.9), whereas that of juveniles ranged from 39.5° to 41.5° (mean, 40.3), indicating that larger snakes have higher temperatures than juveniles, appearing to be proportional to body weight and length in the latter.

Comments upon hibernation, ectoparasites, homing, and population sizes are included.

## INTRODUCTION

Few reports concerning the biology and ecology of the queen snake have been published, the literature generally being limited to check lists, field guides and handbooks. Only three short observations on *Regina septemvittata* in Kentucky have been published (Funkhouser, 1925; Barbour, 1968; Welter and Carr, 1939). The purpose of this report, then, is to present the results of our observations on certain aspects of the life history of Kentucky queen snakes, and to compare our ecological findings with reports from other areas. Our study ran from September, 1968 to September, 1969. During this period, we concentrated primarily upon food preferences, reproduction, temperature, home range and size variation, and habitat.

Based upon his field experiences in six states, Conant (1960) summarized the optimum habitat of *Regina septemvittata* as one of small to medium, permanent, relatively shallow streams with slight to moderate current, often with rocky banks and bottoms, usually in woodland surroundings. The species is normally absent from lakes and ponds

EDITORIAL COMMITTEE FOR THIS PAPER:

DR. HAROLD A. DUNDEE, Associate Professor, Department of Biology, Tulane University, New Orleans, Louisiana 70118

DR. HENRY S. FITCH, Professor of Zoology and Director of the Natural History Reservation, The University of Kansas, Lawrence, Kansas 66044

and from mountain brooks and rills with heavy shade and high gradient. The habitat must be open enough for an abundance of sunshine for at least a few hours each clear day. The queen snake is not entirely confined to such habitats, however, for it is also found occasionally at the edge of marshes and in drainage canals and ditches. Wood's (1949) southwestern Ohio observations indicated that the rate of water current did not appear to have direct bearing on distribution, but that three conditions did appear necessary before large populations could develop: (1) permanent water areas, running or standing, where the water temperature remains at or above 65° F during most of the active season; (2) an abundance of cover, usually flat rocks lying partly in the water; and (3) an abundance of crayfish of the genus *Cambarus*.

Nakamura and Smith (1960) asserted that *Regina septemvittata*, as well as other members of the *Regina* group, are chemically cued to feed upon invertebrates. This observation was more or less corroborated by Burghardt's (1968) significant laboratory investigation on food and chemical preferences in young *Natrix sipedon*, *Regina grahami* and *R. septemvittata*. He found that *N. sipedon* preferred fish and amphibians, whereas *R. grahami* and *R. septemvittata* selected crayfish, especially newly molted *Cambarus*. However, many writers recognize that members of this group of snakes occasionally do eat vertebrates. Conant and Bridges (1939), for example, listed crayfish, fish and frogs in the queen snake's diet. Other items which have been reported from queen snake stomachs are: minnows (Minton, 1944); newts (Wright and Wright, 1957); mudminnows, snails of the genus *Physa*, and fairy shrimp (Adler and Tilley, 1960).

As concerns mating behavior and breeding habits, the literature is quite mute on *Regina septemvittata*, although there have been some reports on litter size and/or embryo counts (see below).

## Materials and Methods

*Food Preference and Feeding Habits.* Food preferences of the queen snake were investigated by two methods: by tempting the snakes with various food items under laboratory conditions, and by dissection and examination of stomach contents of freshly captured specimens. Partially natural habitat conditions (excluding running water) were simulated by setting up two 15-gallon aquaria with natural creek gravel banked so that a portion remained above water level. A medium-sized flat rock was placed on the sand and partially submerged in the water to provide shelter for the snakes. These tanks were covered with full-aquarium hoods, lighted by fluorescent bulbs connected to a timer, by which a photoperiod was established (6:00 a.m. until 9:00 p.m.). The tanks were placed in a constant temperature room (27°) with no windows or other sources of light. During the photoperiod, the temperature reached 31° in the tanks because of heat given off by the light bulbs. A red 40-watt bulb was placed behind and slightly above each tank in order to facilitate post-photoperiod observations. The specimens were allowed to remain in the tanks for one week before food was offered in order to allow adjustment to the new habitat and to insure readiness to feed.

The food habits and preferences in nature were investigated by performing gut analyses of 120 specimens. This sample included 40 specimens captured in June, 40 in July, and 40 in August. In order to establish whether or not a preferred feeding time existed, some specimens were captured during the morning and some during the afternoon. The specimens were also taken at various stations to determine if feeding habits varied between populations. However, this was determined more by availability of specimens than by specific numbers at each station.

After measurements were taken in the field (see below), each specimen was decapitated and preserved in 10% formalin. Analyses of stomach, fore-gut and hind-gut contents were conducted in the laboratory.

*Reproduction.* The environmental set-up utilized for food preference observations was also used for the reproductive study. Ten gravid females, captured during July and the first two weeks of August, were placed in the aquaria and kept under the same photoperiod and temperature regimen as the specimens used for the food preference study until young were presented.

*Body Temperature and Critical Thermal Maxima.* Cloacal temperatures were determined for all specimens used in the study by means of a Schultheis quick-recording reptile thermometer graduated to 0.1° C. Water and air temperatures at the point of capture of each specimen were taken and recorded on data sheets with the cloacal readings.

Specimens used for critical thermal maxima (CTM) determinations included ten adults and ten young-of-the-year without regard to size and sex. All twenty specimens were captured at Station I Tates Creek between the hours of 4:00 p.m. and 6:00 p.m., August 20, 1969, and removed immediately to the laboratory for testing. In order to determine the CTM of the species, and to compare that of the adult with that of juveniles, each specimen was measured, weighed, and measured for temperature. Each individual was placed in the CTM apparatus and recordings were secured.

The CTM apparatus, a modification of those used by Zweifel (1957) and Hutchison (1961), consisted of a variable transformer, a hemispherical heating mantle, a 3000 ml, three-necked distillation flask, and a centigrade thermometer calibrated to 1.0°. The flask was filled approximately half-full of aquarium gravel. The flask was then placed in the heating mantle and the variable transformer was adjusted so that the rate of heat-rise was approximately 0.5° per minute, i.e., slow enough to prevent heat shock, yet fast enough to prevent acclimation. Specimens were placed in the flask through the center neck, whereas the remaining two necks contained the thermometer and a short glass tube for the escape of expanding air. Body writhing or loss of righting response was taken as the point of CTM.

*Population Size, Home Range, Migration, and Homing.* In order to measure these interrelated parameters, five stations were chosen on Otter Creek. All specimens released at these stations were marked by a modification of the method used by Blanchard and Finster (1933), i.e., notching the scutes anterior to the vent with one, two or three notches. The resulting pattern was: A1, B1 . . . Zn, and combinations of the marks (A1–B1, D2–R3, etc.). The notches were incised with a small pocket clip designed for marking laboratory animals such as rats and mice.

Population densities at the stations were determined by the standard capture-release-recapture method devised and used by such workers as Petersen, Lincoln, and Jackson (Kendeigh, 1961).

The investigation of home range and migration resolved itself to keeping adequate records on the points of release and recapture of the marked individuals, and measuring the distance between these two points. The direction from the point of release to the point of recapture was also recorded (up, down, or across the stream).

## Study Area Characteristics

The specimens used in this study were secured from three of the seven creeks that drain Madison County, Kentucky: Silver, Tates, and Otter.

Silver Creek, a tributary of Kentucky River, is formed southeast of Berea by the union of two forks. It flows 39.02 miles, has 60 tributaries, and drains approximately 83,000 acres. The banks are lined with a mixture of sycamore, tulip poplar, elm, beech, oak, box elder, maple, hickory, white ash and willow.

Tates Creek heads within Richmond city limits, and becomes confluent with the Kentucky River at Valley View, Kentucky. It flows 11.8 miles, repeatedly crossing State Highway 169 which parallels the stream for its entire course. The vegetation along its banks is similar to that of Silver Creek.

Otter Creek drains the northeastern portion of Madison County, its origin also lying within Richmond city limits; it flows into Kentucky River about two miles upstream from Fort Boonesborough State Park. The creek is formed by the convergence of three tributaries: Otter Creek proper, West Fork and East Fork. West Fork, heading near White Hall, merges with Otter Creek near Red House at the State Highway 388 crossing. East Fork, rising at Meadowview, merges with the main stream 1.5 miles farther downstream. The vegetation along Otter Creek is similar to that of Silver Creek.

## Description of Stations

In the following discussion, the term "station" is used to designate collecting areas, although such areas often extend several hundred yards rather than being merely a sampling point. The food-preference study was conducted at two or more stations in all

TABLE 1. Capture sites for all specimens of *Regina septemvittata* discussed in text.

| | Stations | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Otter Creek | | | | | Tates Creek | | Silver Creek | | | | Totals Per Month |
| Month | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 1 | 2 | 3 | 4 | |
| 10/68 | 1 | 5 | – | – | – | – | – | 3 | – | – | – | 9 |
| 11/68 | – | 2 | – | – | – | – | – | – | – | – | – | 2 |
| 04/69 | – | 4 | – | – | – | – | – | 3 | – | – | – | 7 |
| 05/69 | 3 | 12 | – | – | – | – | – | 2 | – | – | – | 17 |
| 06/69 | – | 6 | – | – | – | 6 | – | 4 | 18 | 11 | 5 | 50 |
| 07/69 | 10 | 8 | – | – | – | 1 | 34 | – | 12 | 1 | – | 66 |
| 08/69 | 2 | 12 | – | – | – | 40 | 15 | – | – | – | – | 69 |
| 09/69 | – | 5 | 4 | – | – | – | – | – | – | – | – | 9 |
| Totals Per Station | 16 | 54 | 4 | 0 | 0 | 47 | 49 | 12 | 30 | 12 | 5 | Grand Total 229 |

three creeks. Since the streams are very similar, only the location and most prominent characteristics of each station are noted. Due to the length of the stations, parameters such as stream width, depth and velocity, and rock size have little meaning and are omitted.

*Silver Creek.* Station I: at the first bridge on Barnes Mill Road, 6.7 miles west of Richmond; 500 yards. Station II: Taylor's Fork, 3 miles southwest of Richmond; 880 yards long. Station III: at point where Bogie Branch enters the creek, Barnes Mill Road, 8.5 miles northwest of Richmond; 400 yards long. Station IV: at end of Barnes Mill Road, 9.2 miles northeast of Richmond; 145 yards long.

*Tates Creek.* Station I: at Million, Kentucky on State Highway 169, 5.8 miles northwest of Richmond; 400 yards long. Station II: 0.5 mile downstream from Station I; 700 yards long.

*Otter Creek.* Station I: State Highway 388 crossing, Boonesboro, Kentucky, 3.1 miles above Boonesborough State Park; 210 yards long. Station II: 0.9 mile above Station I; 259 yards long. Station III: 0.4 mile above Station II (mouth of Stony Run Branch); 590 yards long. Station IV: East Fork of Otter Creek at State Highway 388 crossing; 335 yards long. Station V: main Otter Creek, 0.3 mile above Station IV (mouth of Lost Fork Creek); 150 yards long.

## Results

The snakes studied were hand-captured by overturning rocks during visits to the stations listed above. No schedule of station visitation was adhered to, although visits were made in all seasons, at various times and under various conditions. Several night visits were made (10 p.m. to 3 a.m.). By inspecting various other localities in Madison County, including farm ponds, still-water pools, and running water, the queen snake was found to frequent only permanent bodies of flowing water, a habitat type which seems to vary little throughout the snake's range (Raney and Roecker, 1947; Green, 1937; McCauley and East, 1940). The species has, however, been collected from non-flowing waters in Ohio (Conant, 1938a), Missouri (Anderson, 1965) and Illinois (Weed, 1922). Of the eleven collecting stations established by us, only two failed to yield specimens. No specimens were found in Otter Creek IV or V. These two stations were considerably dissimilar to the others; station IV provided abundant cover but was discontinuous and non-flowing during much of the summer, becoming almost completely dry during parts of July and August; station V was constantly flowing, but lacked sufficient cover for the snakes.

Table 1 lists all collecting stations and the number of specimens collected at each. Otter Creek II was collected most frequently and it yielded more specimens than any other station. Tates Creek II produced the most specimens per visit (average 16.3), whereas Silver Creek II was second (15.0) and Tates Creek I third (10.2). However, Silver Creek II included more than twice the area of Tates Creek I. The combined yield of these three stations was 126 snakes, or 50.6% of the total specimens secured during the investigation. These stations are similar in make-up, all possessing shallow, slow-moving riffles with many small to large rocks. Tates Creek I lacks canopy cover, and Tates Creek II and the lower half of Silver Creek II are bordered by trees on one side only; their canopy cover varies between 10 to 20%. There is a complete absence of large deep pools and of steep, rapid waters, and the current is continuous throughout the year.

The queen snake, which Smith (1961) termed the stream counterpart of *Regina grahami*, is shy and difficult to capture except when encountered beneath rocks; the snake is an excellent swimmer. Our specimens were never located more than ten feet from water, and even then they were nearly always under rocks. There is some indication that temperature influences the distance at which queen snakes may wander away from water, i.e., the lower the ambient temperature the greater the distance from water. Our evidence on this point, however, is not conclusive and should be verified.

Of the 229 specimens taken during the study period, 95.6% were found beneath rocks, and in water versus on land in a 1.26:1 ratio. Only 1.8% of the specimens were found basking on rocks or on overhanging branches. Four specimens were excavated from a clay bank, four to 10 inches below the surface, in what appeared to be a network of crayfish burrows. Five snakes were encountered beneath other debris, and a large female was removed from a small hole in a sycamore tree, three feet above the waterline. From our field observations, Kentucky queen snakes appear to prefer a canopy cover of 0 to 50% (mean = 15%). Areas possessing cover greater than 50% seem to be avoided.

According to Raney and Roecker (1947) and Wood (1949), queen snakes are frequently found under rocks in gregarious gatherings of three or four specimens, often in the company of one or more *Natrix sipedon*. Wood (1944) described a prehibernation aggregation of 32 queen snakes in central Ohio, and Wood and Duellman (1950) reported similar aggregations from the same state in September, 1946. They collected 125 specimens from a shallow, rocky creek in a linear distance of 100 yards, locating as many as 24 specimens from a single site. Neill (1948) observed such an aggregation at Richmond County, Georgia. He suggested that the entire population of the creek was represented in this single aggregation. However, hibernation has apparently not been reported in the queen snake, although Conant (1938a) found a specimen lying on the January ice of a small creek in Ohio. Upon being warmed to room temperature, the snake appeared to be in good condition and continued living in captivity for several months thereafter.

On several occasions we found queen snakes under rocks with one or more *N. sipedon*. More often, however, we found assemblages of *N. sipedon* separated by short distances from similar groups of *R. septemvittata*. Moreover, *N. sipedon* seemed to be more abundant in rapidly flowing waters, whereas *R. septemvittata* was more or less restricted to quieter waters. Night observations indicated that although *N. sipedon* was active at that time *R. septemvittata* was nocturnally retiring. The specimens of the latter species were located under rocks.

*Hibernation and Seasonal Activity.* The literature, as touched upon above, contains very few reports on the seasonal activity of queen snakes. Conant (1938b) reported the first spring appearance as May 6, and the fall disappearance sometime in October. Raney and Roecker (1947) listed May 10 and September 23, respectively, as spring appearance and fall disappearance dates. In Kentucky, we found these dates to be April 5 and November 15 during the investigative period. The prehibernation aggregations mentioned above did not occur in our study areas, and we were unable to locate any hibernating snakes.

*Food Preference.* Following a one-week adjustment period, two tadpoles (*Rana* sp.) were placed in each experimental tank. One week later, six hard-shelled crayfish were added, three *Orconectes juvenilis* Hagen and three *Cambarus* sp. After three additional days had passed, three soft-shelled *Orconectes* were offered; no soft *Cambarus* were secured. Finally, a week later, six large meal worms (*Tenebrio* sp.) were placed in each tank. After two days, one of the tadpoles was eaten, but it was disgorged the same day with little signs of digestion. The only other food that was taken was two soft-shelled *Orconectes*. Three of the crayfish died and were left in

TABLE 2. Gut Analyses of 120 *Regina septemvittata* with Data Listed by Date and Collecting Station.

| Date | Number Stomachs Examined | Number With Food | Percent With Food | Crayfish: *Cambarus* | Crayfish: *Orconectes* | Crayfish: Not Determined | Crayfish: Total | Percent of Total Food | *Etheostoma flabellare* | Percent of Total Food |
|---|---|---|---|---|---|---|---|---|---|---|
| 6/69 | 40 | 38 | 95 | 4 | 20 | 25 | 49 | 96 | 2 | 4 |
| 7/69 | 40 | 38 | 95 | 1 | 24 | 19 | 44 | 100 | 0 | 0 |
| 8/69 | 40 | 34 | 85 | 0 | 25 | 28 | 53 | 100 | 0 | 0 |
| Grand Totals | 120 | 110 | 91.7 | 5 | 69 | 72 | 146 | 98.6 | 2 | 1.4 |
| Stations | | | | | | | | | | |
| Tates Creek I | 20 | 18 | 90 | 1 | 18 | 14 | 33 | 100 | 0 | 0 |
| Tates Creek II | 41 | 40 | 97.6 | 1 | 25 | 24 | 50 | 100 | 0 | 0 |
| Silver Creek I | 3 | 3 | 100 | 0 | 0 | 1 | 1 | 33.3 | 2 | 66.7 |
| Silver Creek II | 31 | 27 | 87.1 | 3 | 14 | 18 | 35 | 100 | 0 | 0 |
| Silver Creek III | 11 | 11 | 100 | 0 | 8 | 3 | 11 | 100 | 0 | 0 |
| Otter Creek I | 2 | 1 | 50 | 0 | 1 | 2 | 3 | 100 | 0 | 0 |
| Otter Creek II | 12 | 10 | 83.3 | 0 | 3 | 10 | 13 | 100 | 0 | 0 |

the tanks, but the snakes made no attempt to ingest them.

Table II presents the results of gut analyses performed during June, July and August, 1969. Of the 120 stomachs examined, 110 (91.7%) contained food, 98.6% of which was composed of crayfish; the remaining 1.4% was comprised by two *Etheostoma flabellare* Rafinesque. Of the 146 total crayfish found, 72 (49.3%) were digested beyond recognition. The remaining 74 crayfish were diagnosed as *Orconectes juvenilis* (69, or 93.2%) and *Cambarus* sp. (5, or 6.8%).

Several guts contained the remains of more than one crayfish, but these were in the minority. Of the 108 guts containing crayfish, 81 (75%) had one each; 20 (18.5%) had two each; five (4.7%) had three each; one (0.9%) had four; and one large female from Tates Creek II contained six *O. juvenilis*.

By collecting at various times of the day, the investigators determined that feeding was most prevalent during the early morning hours (8 to 10 a.m.) and during the late afternoon (4 to 6 p.m.).

Gut analyses by station (Table II) demonstrated little variation in food habits. Three of the five *Cambarus* were removed from Silver Creek II specimens, and both fantail darters were taken from Silver Creek I snakes. There was no discernible difference in the types or amounts of food taken by the queen snake during the sampling periods.

Although these findings confirm the concensus of several investigators that the bulk of the queen snake's diet is crayfish, our examination of stomachs demonstrated little correlation between the size of the snake and the size of the prey taken, since small snakes often had very large crayfish in their guts.

During our food preference observations, a female queen snake approached a hard-shelled *Orconectes* and was immediately attacked and driven away, lending credence to the supposition that this snake probably could not catch and eat a well-armed, fully mature crayfish as suggested by Wood (1949). This may indicate either that the queen snake eats dead specimens or newly molted ones. A crayfish about to undergo ecdysis retreats to the cover afforded by rocks and at that time could be easily ingested by even a small queen snake. Some evidence for this was furnished when we surprised a large snake beneath a rock in the water; the snake had partially swallowed a 2.5-inch soft-shelled *Orconectes*, which was abruptly disgorged. Other evidence comes from the food preference study, where we observed that only newly molted crayfish were eaten. We cannot support Wood's (1949) idea that queen snakes eat dead crayfish. Hall (1969) reported that *R. grahami* swallowed crayfish head-first and tail-first in a 1:1 ratio. Of all the crayfish taken by queen snakes during our study, only one had been swallowed head-first. This indicates that prey is taken from ambush rather than being caught by chase, or, that the crayfish were turned before being swallowed.

Contrary to the findings of Wood (1949), Raney and Roecker (1947). Conant (1960), and Burghardt (1968), all of whom indicate that crayfish of the genus *Cambarus* constitute most of the snake's diet, the queen snakes of Madison County, Kentucky feed almost exclusively on *Orconectes juvenilis*. These findings more or less parallel those of Penn (1950) who stated that 94% of New York, Pennsylvania and Virginia queen snakes contained *Orconectes obscurus* Hagen. In Kentucky, the reason for this is that the ratio of the two genera of crayfish in our study streams strongly favors *Orconectes*. Three of the five *Cambarus* found in the guts of snakes were from individuals collected at Silver Creek II. This station originates in Wilgreen Lake, the mud banks of which support a larger population of *Cambarus* than the environments at any of the other stations. Crayfish sampling demonstrated a ratio of 8.6:1 *Orconectes* to *Cambarus* at Silver Creek II, whereas at all other stations the ratio was about 9:1. Furthermore, most specimens of *Cambarus* were found either under rocks well away from the water or in burrows above the water line. This evidence indicates that the queen snake is an opportunistic feeder which takes any crayfish that presents itself. The inclusion of small vertebrates in the diet, such as tadpoles, is probably fortuitous rather than the result of active seeking.

*Reproduction.* Of 229 specimens examined, 113 were males and 116 were females, or essentially a 1:1 sex ratio. The sex ratio of young born in captivity (128) was 65 males and 63 females, also close to a 1:1 ratio. Fifty-seven of the females dissected for gut analyses were utilized to determine sexual maturity. Thirty-five contained immature eggs, mature eggs, or embryos, or had recently given birth to young (Fig. 1). The number of young that had been presented by each female was ascertained by counting the stretched pockets in the oviducts. The 35 specimens contained from 7 to 49 (mean = 25.1) immature eggs. Fifteen specimens (42.8%) contained only immature eggs; most of these specimens were captured during June and July. However, one snake, containing seven eggs, was captured on August 13. Only two specimens (5.7%) contained immature and mature eggs, and both were captured during June. Four snakes (11.5%), three of which were taken in August and the other one in June, contained immature eggs and embryos. The last 14 specimens (40%), all taken August 12–13, contained immature eggs and had given birth. The number of young per litter varied between 7 and 17, totaled 163, and averaged 11.6 per litter.

Another criterion which has been utilized for the determination of sexual maturity is size. Wood and Duellman (1950) considered 375 mm total length as the point between maturity and immaturity. Generally, this was true of our specimens, as confirmed by dissection, but one 344 mm female contained 10 immature eggs. This is probably, however, near the minimal size for a sexually mature queen snake. The largest snake which lacked eggs was 454 mm total length, captured on August 12, 1969. The total length of 18 immature specimens ranged from 242 mm in June to 454 mm in August (mean = 315). These specimens were doubtless in their first year of growth. The 344 mm specimen falls into this category, thereby presenting some evidence that young females may develop a few immature eggs late in the fall of their first year. Specimens containing only immature eggs ranged from 344 mm to 592 mm (mean = 507.4) in total length and, with the possible exception of the 344 mm and 376 mm specimens, evidently were in their second year of growth. Specimens containing mature eggs, embryos, or ones which had given birth to young, ranged from 585 mm to 757 mm in total length (mean = 677.2), and we judged them to be in their third or subsequent year. How-

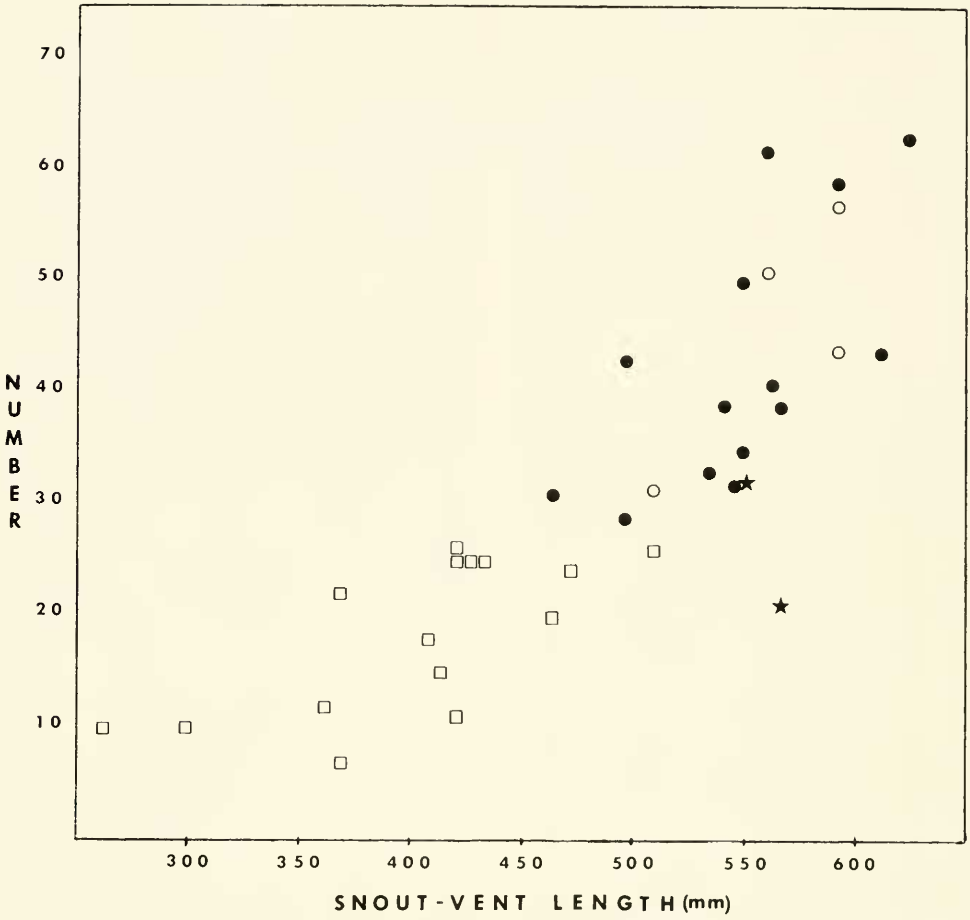


Figure 1. Snout-vent lengths of 35 *Regina septemvittata* correlated with numbers of mature and immature ovarian eggs, embryos or young. Squares = specimens with immature eggs only; stars = specimens with both immature and mature eggs; open circles = specimens with immature eggs and embryos; closed circles = specimens with immature eggs which had presented young.

ever, age cannot be accurately determined by size beyond the third year due to reduction in growth rate (Wood and Duellman, 1950).

Our evidence indicates that female queen snakes generally do not reach sexual maturity until the second year of life, and that they probably do not reproduce until the third year. Mating probably occurs during the fall of the second year or in the spring of the third. As far as we were able to determine from development of the testes and seminal vesicles, and from growth patterns, male queen snakes also become mature during their second year and probably mate that fall, or during the spring of their third year. However, sperm smears were not made to substantiate this deduction.

The presence of immature eggs in specimens which had produced litters possibly indicates that such eggs represent the following year's litters, and further, that immature eggs are produced at least one year in advance of reproduction. If true, the validity of our hypothesis regarding the age at onset of reproduction in female queen snakes should be obvious. Tinkle (1962) observed this type of cycle in *Crotalus atrox* Baird and Girard in Texas, indicating that the female usually does not have energy reserve to produce broods each year. However, in light of

TABLE 3. Place of Capture, Weight, and Total and Snout-Vent Lengths of Mothers of Ten Litters of Young, and Birth Dates and Number of Young. Lengths in mm; Weights in gms.

| Young | | | Mothers | | | |
|---|---|---|---|---|---|---|
| | | | | Length | | |
| Litter | Number | Birth Date | Place of Capture | Total | Snout-Vent | Weight |
| 1 | 16 | 8/04/69 | Otter Creek I | 725 | 585 | 83.0 |
| 2 | 14 | 8/04/69 | Otter Creek I | 699 | 585 | 71.5 |
| 3 | 11 | 8/04/69 | Otter Creek I | 643 | 502 | 59.8 |
| 4 | 11 | 8/05/69 | Otter Creek I | 776 | 636 | 122.4 |
| 5 | 13 | 8/11/69 | Otter Creek II | 840 | 678 | 137.8 |
| 6 | 13 | 8/13/69 | Otter Creek II | 738 | 662 | 116.2 |
| 7 | 17 | 8/18/69 | Otter Creek II | 785 | 645 | 113.5 |
| 8 | 12 | 8/20/69 | Tates Creek II | 711 | 571 | 89.8 |
| 9 | 13 | 8/20/69 | Tates Creek II | 674 | 560 | 84.4 |
| 10 | 8 | 9/10/69 | Otter Creek II | 630 | 501 | 56.2 |

our information this is probably not true for the queen snake which we believe produces annual litters following the onset of maturity.

Dissection of several gravid females revealed that viviparity in the queen snake involves more than mere retention of eggs. At all stages of development, the eggs lacked a shell. In specimens with oviducal eggs, the thin chorionic membrane was in intimate contact with the distended oviduct and both became richly supplied with a fine network of blood vessels. Comparison of oviducal eggs at different stages of development demonstrated a notable increase in size, which suggested placental transmission of dissolved solids, an observation similar to that of Hall (1969) in *Regina grahami*, and Clark et al. (1955) in *Thamnophis sirtalis* (Linnaeus).

When the total number of eggs, embryos, and young from each adult are plotted against individual snout-vent lengths (Fig. 1), it can be seen that the number increases with increasing body length. The smallest specimen (344 mm) containing eggs (10) was captured July 7 at Tates Creek II, whereas the largest snake, a 764 mm specimen, was collected on August 12 at Tates Creek I; it contained 49 immature eggs, had given birth to 14 young, and thus presented a combined total of 63. Figure 2 also demonstrates that 75% of the snakes containing mature eggs or young had body lengths of 500 to 600 mm.

Ten gravid females captured during July and August presented young in captivity (Table 3). The number of young per litter varied from 8 to 17 (mean = 12.8), and delivery dates ranged from August 4 to Sep-

TABLE 4. Statistical Analysis of Length and Weight, by Litters and Sex, of Newborn *Regina septemvittata*. Lengths in mm; Weights in gms; S = standard deviation; $S_{\bar{x}}$ = standard error of mean; $\bar{x}$ = mean.

| | | Snout-Vent Length | | | | Weight | | | |
|---|---|---|---|---|---|---|---|---|---|
| Litter | Number | Range | $\bar{x}$ | S | $S_{\bar{x}}$ | Range | $\bar{x}$ | S | $S_{\bar{x}}$ |
| 1 | 16 | 134–169 | 159 | 8.24 | 2.06 | 2.400–2.911 | 2.794 | 0.137 | 0.034 |
| 2 | 14 | 157–170 | 165 | 4.31 | 1.15 | 2.517–3.065 | 2.835 | 0.131 | 0.035 |
| 3 | 11 | 157–170 | 164 | 3.95 | 1.19 | 2.630–2.910 | 2.804 | 0.094 | 0.027 |
| 4 | 11 | 160–171 | 165 | 3.45 | 1.04 | 2.664–2.953 | 2.808 | 0.086 | 0.026 |
| 5 | 13 | 192–204 | 198 | 4.63 | 1.28 | 3.356–4.216 | 3.791 | 0.345 | 0.096 |
| 6 | 13 | 180–192 | 187 | 3.90 | 1.08 | 3.162–3.800 | 3.609 | 0.152 | 0.042 |
| 7 | 17 | 177–203 | 186 | 6.25 | 1.52 | 3.110–4.015 | 3.614 | 0.267 | 0.065 |
| 8 | 12 | 170–210 | 184 | 9.86 | 2.84 | 3.150–4.071 | 3.600 | 0.254 | 0.073 |
| 9 | 13 | 162–200 | 178 | 12.40 | 3.44 | 2.465–3.912 | 3.254 | 0.495 | 0.137 |
| 10 | 8 | 180–202 | 191 | 7.83 | 2.77 | 3.476–4.003 | 3.744 | 0.189 | 0.067 |
| Males | 65 | 134–210 | 177 | 15.69 | 1.94 | 2.400–4.199 | 3.255 | 0.487 | 0.060 |
| Females | 63 | 159–203 | 178 | 13.55 | 1.70 | 2.630–4.216 | 3.296 | 0.059 | 0.007 |
| Combined | 128 | 134–210 | 177 | 14.59 | 1.29 | 2.400–4.216 | 3.279 | 0.477 | 0.042 |

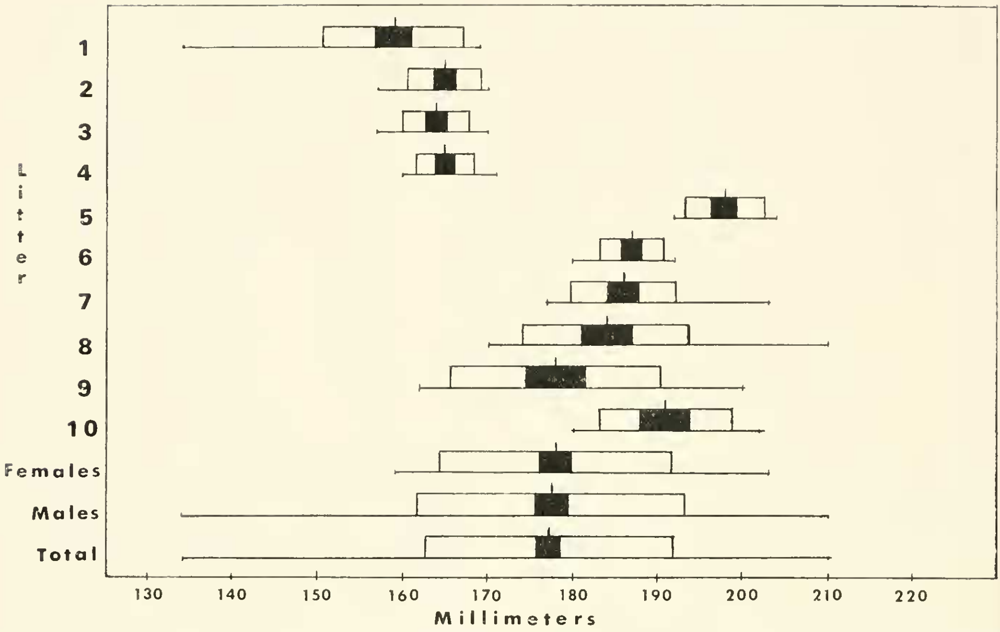


Figure 2. Snout-vent length data for young *Regina septemvittata* (see Table 4). Horizontal line = range; vertical line = mean; open box = standard deviation mean; filled box = two standard errors on each side of mean.

tember 10. Dunn (1915) reported 5 per litter in Virginia, Triplehorn (1949) 23 per litter in Ohio, and Funkhouser (1925) stated that broods of 30 to 40 were not uncommon in Kentucky snakes. Additional reported measurements for newborn queen snakes may be found in Hudson (1954), Anderson (1965), Wood (1949), Swanson (1952), McCauley (1945), Conant (1938b), and Minton (1944). Several reports of number of young have been published, including those of Pope (1944), and Barbour (1968) who gave a range of 5–18. Total and snout-vent lengths for our observed litters are compared in Table 4 and in Figs. 2 and 3. Although sex ratios varied widely within a given litter, the total number (128) numbered 63 females and 65 males, or very close to a 1:1 ratio. As shown in Table 4, the weight varied between 2.400 gms and 4.216 gms (mean = 3.279).

The only records for newborn queen snakes are those of Burghardt (1968). A litter of 20 young, born August 18 in Illinois, averaged 161 mm in snout-vent length and 2.937 gm in weight. Our data for snout-vent length is presented in Figure 2, and that for weight in Figure 3. Litters one through four differ from litters five through 10. The mothers of the first four litters were collected at Station I of Otter Creek (Table 3). Litter one, presented a few days prematurely differs slightly from litters two, three and four (Figs. 2, 3). Litters five and 10 differ from litters six, seven, eight and nine, both in length and weight. Table 3 also demonstrates that the mother of litter five was much larger than the other females, and that litter 10 was produced on September 10, at least three weeks later than the others. Although the 10 litters differed considerably among themselves, there was no obvious difference between males and females, and neither sex differed in these particulars from those of the combined total.

The process of birth was observed in eight of the 10 litters born in captivity. As the female became ready to present young, pronounced swellings developed at the posterior two-thirds of the body. Gentle convulsive twitchings affected the same area. During presentation of young, the vent was raised two to three cm and the tail was arched and moved slowly from side to side as the con-

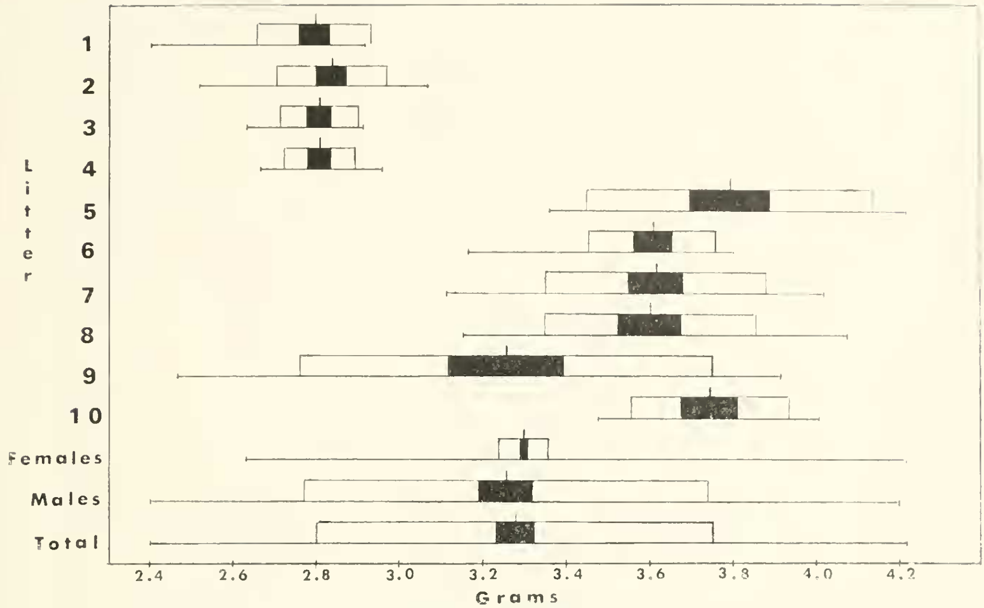


Figure 3. Body weight data for young *Regina septemvittata* (see Table 4). Symbols as in Fig. 3.

vulsive waves passed caudad. The amnion sac appeared first, followed by the allantois and the yolk sac. In many cases the young snakes broke the amnion sac before being completely delivered, depending upon delivery position. Some young were presented head-first and some body-loop first. Those that did not break the sac by forcing their heads through it during birth did so within seconds after delivery.

The females did not always remain in the same place while presenting young, sometimes crawling around the cage, stopping periodically to present another young. The mother snakes did not pay much heed to their young, and crawled over them repeatedly. However, this may be a reflection of captivity.

The time required for individual births ranged from 1.5 minutes to 2.5 minutes, and the time-lapse between births ranged from four minutes to one hour (mean = 11 minutes). There seems to be no special time of the day during which young are presented. Of the 10 litters, four were presented between 6:00 a.m. and noon, four between noon and 6:00 p.m., and two litters were presented during the night.

Within seconds after breaking the amnion with the head, each young snake opened its mouth widely, and breathing rhythms and tongue flicks followed immediately. No attempt was made to determine breathing or heart rates in the young. The umbilical cord was attached to the yolk sac and to the young snake at a point about 15 mm anterior to the vent. The young snakes were capable of frolicking and swimming moments after birth, and the amount of activity determined how long the umbilical cord remained attached. In some cases, the yolk sac was dragged about for three to four hours. Within 24 hours after birth, all young completed shedding the thin skin. Another molt involving a thicker skin followed approximately four days later.

All 16 snakes of the first litter were prematurely born, and were unable to break the amnion. Considerably more yolk remained in the yolk sac of these specimens than in those of the other litters. Two of these premature snakes, still contained in the amnionic sac, were alive after 10 hours. Efforts to free them succeeded, but they soon died. One male had a fused body loop and a total body length of 172 mm.

A method for sexing the young was devised in which the snake was turned ventral

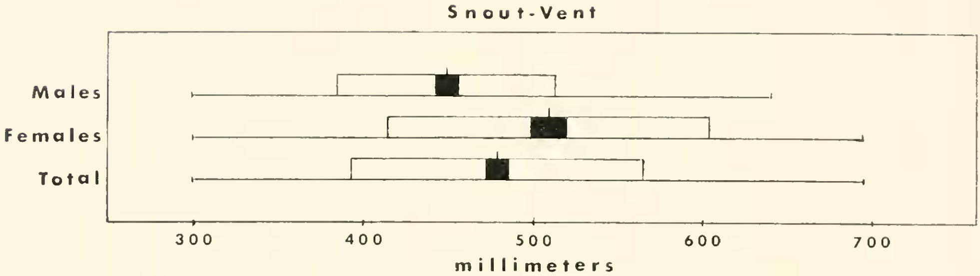


Figure 4. Snout-vent length data for adult *Regina septemvittata*. Symbols as in Fig. 3.

side up and the right thumb placed slightly posterior to the vent with the forefinger resting beneath the specimen's back. A moderate pressure applied by this method caused the hemipenes of the males to become everted.

Although the young queen snakes refused to feed in captivity, our field investigation revealed that young-of-the-year in the wild do feed between the time of birth and hibernation, and in every case the food was soft-shelled *Orconectes*.

*Size and Growth Rate.* Comparing snout-vent lengths for our data on 179 adult snakes (90 males; 89 females) showed that the sexes differed (Fig. 4), ranging from 299 to 642 mm (mean = 448.9) in males, and from 299 to 695 mm (mean = 509.1) in females. Smith's (1961) measurements of 30 Illinois snakes indicated that the tail occupied 26 to 28.6% (mean = 27.2) of the total length in 10 males and 19.9 to 26.9% (mean = 24.5) in 20 females, and Wood and Duellman (loc. cit.) reported 23.0 to 29.0% (mean = 25.0) for 73 Ohio males and 19.6 to 26.5% (mean = 22.8) for 60 females.

The literature is meager on queen snake growth rates. One estimate (Raney and Roecker, 1947) was based upon 17 recently born specimens, 217 mm in average length, and 21 yearlings averaging 390 mm in length; the calculated average increase in length was 173 mm, or 79%. Raney and Roecker thus indicated that the growth rate in the queen snake was about the same as in *Natrix sipedon*. Blanchard and Finster (1933), however, found that the annual increase in Michigan populations of *N. sipedon* was about 50% in the young, but only approximately 15% in adults; by the third year, the increase was less than 33%. These findings were substantiated in Ohio queen snakes by Wood and Duellman (1950), who reported an increment of 50% during the second year and diminishing growth rates during the third and subsequent years. All writers seem to agree that female queen snakes have a greater annual length increment than males, and they may also attain a greater maximum length.

Maximum size has been listed for *Regina septemvittata* in various parts of its range (Conant, 1938a; McCauley, 1945; Pope, 1944; Triplehorn, 1949; and Wood and Duellman, 1950). The record length appears to be a 922 mm (36.25 inches) female from near Defiance, Ohio (Triplehorn, 1949). The minimum size for a sexually mature queen snake has not been determined, although Wood and Duellman (1950) consider 375 mm as the cutoff point between juveniles and adults.

When the mean total length of our newborn snakes is compared to that of yearlings (242 to 454 mm; mean = 398), an average growth increment of 171 mm, or 75%, is calculated. These data closely approximate the 79% reported by Raney and Roecker (1947) for New York specimens. The mean total length for specimens judged to be in their second year was 576 mm. Comparing this calculation with the mean total length of the yearlings, a putative growth increase of 178 mm, or 44.8%, was computed. This is slightly less than the 50% calculated for Ohio specimens by Wood and Duellman (1950).

Length measurements did not clearly differentiate a third-year class and, therefore, growth for this age group could not be calculated. Growth rates in adult *R. septemvittata* were determined by our capture-release-recapture investigation. A 615 mm specimen released October 24, 1968 and recaptured on July 16, 1969 measured 712 mm

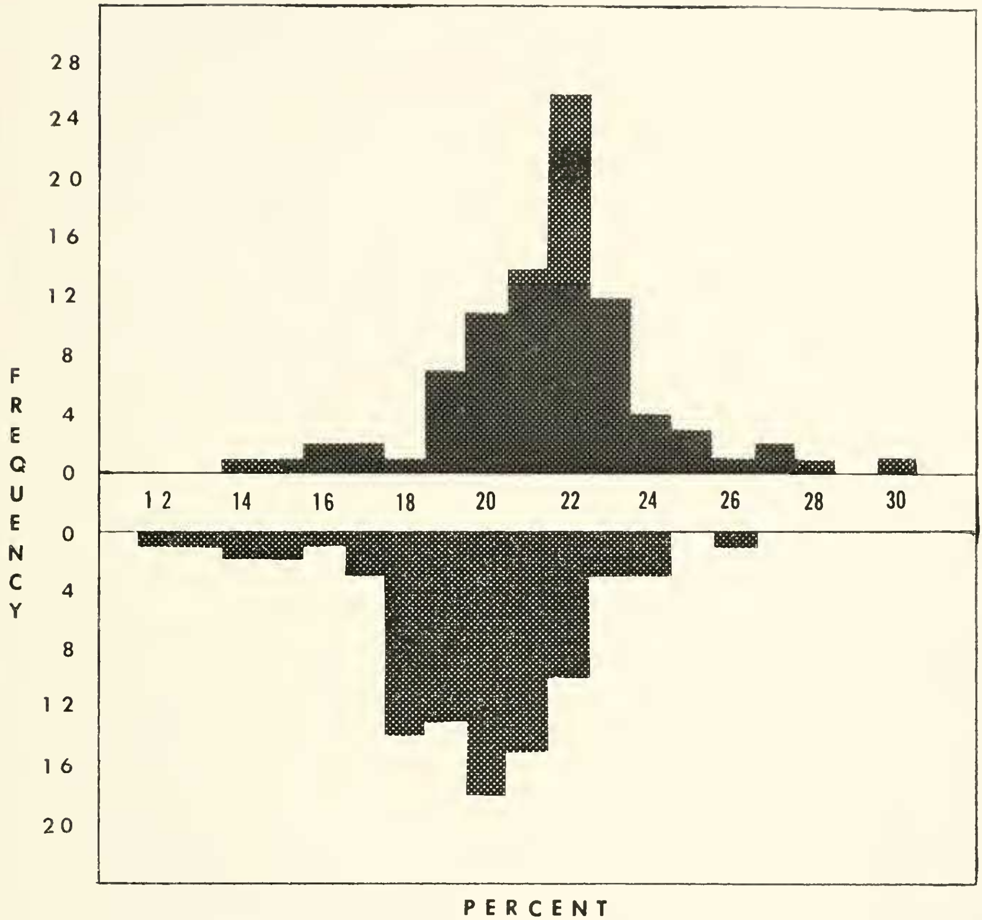


Figure 5. Histograms of tail length/total length for 90 male and 89 female adult *Regina septemvittata.*

in total length, or an increase of 97 mm (15%) over a period of 38 weeks. Similarly, a 738 mm female increased to 840 mm during 42 weeks of freedom (102 mm), or 14%. These figures are close to those of Blanchard and Finster (1933) for adult *Natrix sipedon* (15%), but greater than the 5% reported for *Thamnophis sirtalis.* However, an 850 mm female grew only 5 mm during a period of 42 weeks, or an increase of 0.6%. These data support the idea that older individuals grow more slowly than younger ones. The first specimen recaptured was probably in its fourth season, the second in its fifth, and the third in its sixth or some subsequent year. Other recaptures involved shorter periods of time during summer months only, thus could not be used to determine annual growth rates. It is interesting, however, that the summer growth rates for such individuals averaged approximately 2.5 mm per week.

*Body Temperature and Critical Thermal Maxima.* There seems to be no literature reports on queen snake body temperatures. The specimens were found both in and out of water, therefore, the ambient temperature (Fig. 6) reflects both habitats. Of the 205 specimens, 116 (56.6%) were partially or completely submerged in water, whereas 89 (43.4%) were found out of water. All specimens found in water expressed temperatures ranging from 0.2 to 6.2 degrees (mean = 2.4) above water temperatures. Of the 89 specimens found out of water, 60 (67.4%) had temperatures lower than ambient ones (14.2% of the total number). The highest

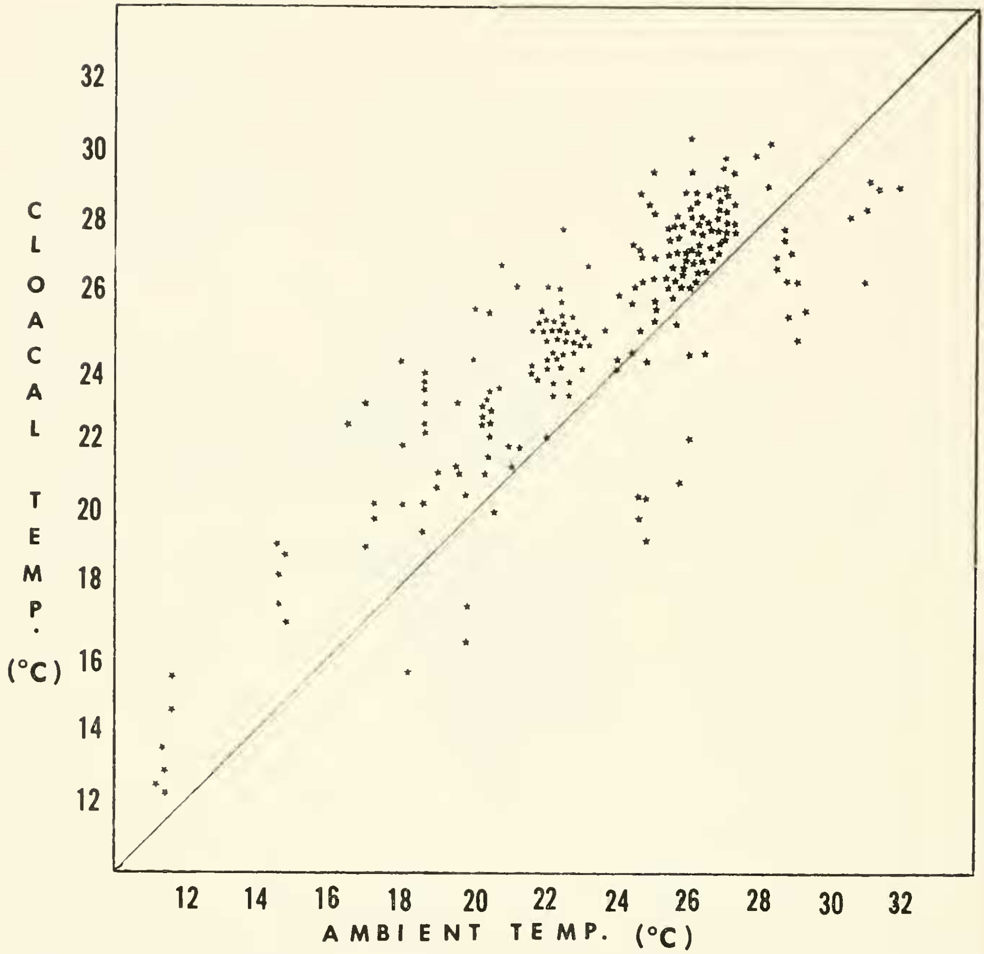


Figure 6. Cloacal temperatures of 205 *Regina septemvittata* compared with ambient temperatures. Diagonal line represents point at which cloacal and ambient temperatures are equal. Stars above line represent specimens with cloacal temperatures higher than ambient; stars below line are specimens with cloacal temperatures lower than ambient.

body temperature recorded during the study was taken on June 30, 1969 from a specimen found in water of 26° C (air 30.8°), 30.4° C. The lowest body temperature was 12.2° C, recorded October 24, 1969 when the air temperature was 8° C and that of the water 11.2°. The mean temperature of all recordings was 25.6° C.

The 29 measurements appearing below the equatorial line in Figure 6 were taken from specimens found under rocks away from water, and the ambient temperature was recorded in the air approximately four feet above ground level. Had these temperatures been measured in the cooler areas beneath the rocks, these 29 specimens perhaps would have also demonstrated body temperatures higher than the ambient. From these observations, it seems evident that *R. septemvittata* can exert some control over its body temperature, maintaining temperatures of at least 6.2° C above the ambient. Lueth (1941) felt that most snakes were able to maintain body temperatures above ambient ones of 0° to 10° C and below ambient temperatures of 30° C. Our data also indicate a correlation between body size and body temperatures, smaller individuals generally showing higher

TABLE 5. Critical Thermal Maxima Comparisons Between 10 Adult and 10 Juvenile *Regina septemvittata*. Temperatures in Centrigrade; Times in Minutes; Weights in gms; Lengths in mm: A = Adult; J = Juvenile.

| Specimen Number | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Initial Flask | A | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| Temperature | J | 25.5 | 25.5 | 25.5 | 25.5 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| Temperature | A | 44.0 | 43.5 | 43.5 | 44.5 | 44.0 | 44.0 | 44.5 | 43.5 | 44.0 | 43.5 | 43.9 |
| at CTM | J | 39.5 | 40.5 | 40.0 | 41.5 | 40.5 | 39.5 | 40.5 | 40.5 | 40.0 | 41.0 | 40.3 |
| Time to CTM | A | 25.0 | 24.0 | 21.5 | 25.0 | 26.0 | 25.5 | 26.0 | 25.0 | 25.5 | 25.0 | 24.9 |
| | J | 19.0 | 19.5 | 19.0 | 20.0 | 19.5 | 19.0 | 19.5 | 19.0 | 19.0 | 19.5 | 19.3 |
| Initial Cloacal | A | 22.5 | 21.0 | 22.0 | 22.4 | 21.4 | 22.8 | 23.2 | 22.4 | 22.6 | 24.2 | 22.5 |
| Temperature | J | 26.4 | 25.0 | 26.8 | 25.2 | 25.3 | 27.2 | 25.8 | 25.5 | 26.6 | 27.0 | 26.0 |
| Body Weight | A | 55.7 | 118.8 | 44.8 | 89.2 | 59.1 | 59.6 | 88.4 | 43.2 | 98.1 | 25.5 | 68.2 |
| | J | 3.97 | 4.31 | 4.26 | 5.05 | 4.59 | 3.84 | 4.10 | 4.25 | 4.05 | 4.84 | 4.33 |
| Snout-Vent | A | 510 | 630 | 455 | 553 | 520 | 515 | 635 | 441 | 580 | 377 | 522 |
| Length | J | 152 | 187 | 184 | 201 | 188 | 148 | 188 | 168 | 160 | 205 | 178 |

temperatures than larger ones. This shall have to be substantiated by more intensive investigation.

Table 5 presents the results of a comparative ctm study between 10 adult and 10 juvenile queen snakes. Initial flask temperatures, time to CTM, and initial cloacal temperatures were taken and recorded to assure that each specimen was tested under similar conditions. For the adults, CTM ranged from 43.4 to 44.5° C (mean = 43.9), while that for juveniles ranged from 39.5 to 41.5° C (mean = 40.3). The data (Table 5) show little or no correlation between body weight or size and the temperature at which the adults reached CTM. However, in the juveniles, where weights and lengths exhibited a much smaller range, there were distinct correlations between body weight and CTM and length and CTM (Table 5). The CTM of juveniles appears to be directly proportional to body weight and length.

It is a well-established principle in reptiles (Lowe and Vance, 1955; Hutchison, Vinegar and Kosh, 1966) and amphibians (Zweifel, 1957; Hutchison, 1961; Brattstrom and Lawrence, 1962) that the temperature to which an animal has been acclimated exerts a significant effect on the level of temperature at which the animal reaches CTM. In this investigation, since the 20 specimens tested were captured at the same hour, at the same location and, in some instances, under the same rock, it was assumed that their thermal histories were the same and, therefore, did not affect the results of testing. Brattstrom and Lawrence (loc. cit.) and Hutchison, Vinegar and Kosh (loc. cit.) reported that CTM depends upon the size of the animal, and that smaller specimens demonstrate higher CTM's. This work, however, disputes these reports in that the larger juvenile queen snakes (determined by weight and length) exhibited higher CTM than the small ones (Fig. 1). Hutchison (1961) found no correlation between body size and CTM in adult salamanders. Our testing indicated no correlation between adult size and CTM, although it did demonstrate a higher heat tolerance in adults than in juveniles. Although a temperature above 43.9° C is required to cause death in adults, the highest voluntary body temperature recorded was 30.4° C. Little is known about the critical thermal minima of the queen snake, although Lueth (loc. cit.) reported these minima as –2° to –5° C in *Natrix sipedon*. The lowest voluntary body temperature recorded for the queen snake during our work was 12.2° C.

*Population Size, Home Range, Migration, and Homing.* Because of inadequate recapture, population size was established only at stations I and II of Otter Creek. The average population at Station I was 35, whereas at Station II it was 62. Table 6 records 13 recaptures involving 10 specimens. The queen snake seems to have a relatively small home range, but shows some tendency to dispersal. Of 13 recaptures, the straight-line distance from point of release to point of recapture varied from about 10 feet to 450 (mean = 74.2), although 11 of the 13 were less than 100 feet. Specimens one and 10 were recaptured twice. Specimen

TABLE 6. Movements and Growth Rates of Marked *Regina septemvittata*. Lengths in mm; Distances in Feet; Time in Weeks. Snakes 47, 51 and 65 were from Otter Creek I; the remainder were from Otter Creek II.

| Specimen Number | Sex | Length When Released | Date of Release | Interval Before Recovery | Length When Recovered | Minimum Distance Traveled |
|---|---|---|---|---|---|---|
| 1 | F | 615 | 10/24/68 | 27 wks. | 662 | 50 ft. |
| 1 | F | 662 | 05/02/69 | 11 wks. | 712 | 150 ft. |
| 3 | M | 555 | 10/24/68 | 1 wk. | 557 | 35 ft. |
| 4 | F | 850 | 10/24/68 | 12 wks. | 855 | 75 ft. |
| 10 | F | 738 | 11/01/68 | 37 wks. | 795 | 50 ft. |
| 10 | F | 795 | 07/16/69 | 5 wks. | 840 | 25 ft. |
| 43 | M | 668 | 06/24/69 | 7 wks. | 674 | 35 ft. |
| 46 | M | 649 | 06/24/69 | 7 wks. | 674 | 40 ft. |
| 47 | F | 643 | 07/15/69 | 1½ wks. | 645 | 10 ft. |
| 51 | F | 776 | 07/15/69 | 1½ wks. | 789 | 20 ft. |
| 54 | F | 789 | 07/16/69 | 3½ wks. | 814 | 15 ft. |
| 56 | M | 624 | 07/16/69 | 3½ wks. | 649 | 10 ft. |
| 63 | M | 617 | 07/24/69 | 2 wks. | 635 | 450 ft. |

one was initially released October 24, 1968, and was recaptured the following spring, May 2, 1969, on the same side of the stream but 50 feet farther upstream. The second recapture was made July 16, 1969, when the snake was found on the opposite side and 150 feet upstream from the point of the second site. The total minimum distance traveled from initial release was 200 feet upstream over a period of 38 weeks. Specimen two was initially captured and released about midway in Station II on November 1, 1968. This female was recaptured July 16, 1969 approximately 50 feet downstream from the point of release; the second recapture was made on August 7, 1969 on the opposite side of the stream, 25 feet upstream from the point of the first recapture. The total minimum distance traveled from the initial release point was 75 feet, but the net distance was slightly more than 25 feet over a period of 40 weeks.

We have no definite evidence of migration, since all recaptures were made in the same vicinity of initial release. However, during the investigation on homing, in which specimens were transported from station to station, no specimens were recaptured. Seven individuals, initially captured at Station II, were marked and released at Station I on May 1, 1969. The same day, six specimens were transported from Station II to Station IV. The following day, three specimens were removed from Station I to Station II. Likewise, specimens brought in from stations on Tates and Silver creeks were never recaptured. On May 14, 1969, two specimens captured at Silver Creek I were released at Otter Creek I, and on June 10, 1969, six specimens were transported from Silver Creek IV to Otter Creek IV. Also, seven specimens were taken from Tates Creek II to Otter Creek II on July 26, 1969, and on August 20, 1969 eight snakes were removed from Tates Creek I to Otter Creek III. A total of 49 specimens were, then, relocated in Otter Creek, but none of these were recaptured. This indicates that these snakes did disperse, but there was no evidence as regards direction, distances, etc.

*Predation and Ectoparasites.* It is very likely that queen snakes may be preyed upon by mice (Wood, 1949) and by other snakes (Huheey and Stupka, 1967) during hibernation. Young snakes are perhaps subject to considerable predation at any time. For example, several of the snakes born in captivity were killed and eaten by the crayfish which had been placed in the tanks as food for adults. Apparently, the crayfish caught and successfully held the young snakes beneath the water until they drowned. On several occasions crayfish were observed attempting to attack the adult snakes. Another instance of predation of young queen snakes was reported by Mr. Ronald Houp, a graduate student at Eastern Kentucky University, in which a hellbender, *Cryptobranchus alleganiensis* (Daudin), was found to have eaten two individuals.

Although all water snakes are subject to numerous parasites (Holl and Allison, 1935), only two types were discovered during our study. Many specimens had numerous white blisters scattered over the body. These blisters increased in number as the snakes prepared to molt, following which most of the blisters were sloughed off with the skin. However, a few remained to reinfect the snake. Individuals kept in captivity developed greater numbers of this parasite than ones secured from nature. Incubation of the contents from one of these blisters proved the parasite to be an undiagnosed species of the fungus genus *Verticellium*. The second instance of parasitism involved a male snake captured in mud, which bore three leeches, probably *Placobdella rugosa* (Verrill), attached to the neck region.

## Summary and Conclusions

The results of our investigations and measurements are reviewed and summarized as follows: *Regina septemvittata* is mildly dispositioned and seldom attempts to bite even during rough handling. The primary means of defense are secretive habits, escape by swimming rapidly and hiding under water, and the utilization of musk glands located on either side of the cloaca. The preferred habitat is constantly flowing streams possessing an abundance of cover, i.e., medium to large, flat rocks, and accompanied by a canopy cover that averages about 15%, seldom exceeding 50%. The snake is seldom found in riffles with a steep gradient, slow riffles and shallow pools being preferred. Although occasionally encountered sunning on rocks and overhanging tree branches, the highly aquatic queen snake was most often found beneath rocks, both in and out of the water, seldom more than 10 feet from the streams. It is not a particularly nocturnal animal.

*Regina septemvittata* is moderately gregarious, with aggregations of two to four specimens occasionally being observed beneath the same rock, sometimes accompanied by one or more *Natrix sipedon*.

The bulk of Kentucky queen snakes' diet (98.6%) is composed of soft-shelled crayfish, 93.2% of which is *Orconectes juvenilis*. Only on three occasions were other foods observed: two fantail darters and a ranid tadpole. The snake is probably an opportunistic feeder, preying upon the most abundant crayfish in the habitat. Prey are taken from ambush rather than by chase, or the crayfish are turned before swallowing, as determined by attitude in the gut. Feeding was more frequent between 8:00 a.m. and 10:00 a.m., and between 4:00 p.m. and 6:00 p.m. than at other times of the day. Food habits varied little between collecting stations and different times of the year. Young-of-the-year also utilized soft-shelled *Orconectes juvenilis*.

A 1:1 sex ratio, both in adults and in newborn was observed. Females generally do not reproduce until their third year, although immature eggs may be found early during the second year, and possibly are produced in late fall of the first year. The minimum size of a mature female observed was 344 mm total length. Males appear to become sexually mature during the second year. Mating probably occurs both in spring and fall, with young females mating for the first time during the fall of their second year or in the spring of their third year. Dissected females contained from 7 to 49 immature eggs, in addition to mature eggs or embryos, or were recognized as having given birth. The immature eggs probably represent the reproductive potential for the following season, thus indicating an annual reproductive cycle rather than a biannual one. The total combination of eggs, embryos, and empty follicles (young produced) increases proportionally with body size.

The queen snake is viviparous, and the retained eggs lack shells at all stages of development. The thin chorionic membrane of oviducal eggs lies in intimate contact with the distended oviduct during development. A notable increase in egg size indicates transmission of dissolved nutrients. The young were born in captivity from August 4 to September 10, 1969, the number per litter varying from 8 to 17, averaging 12.8 per female. During parturition, the amnion sac appears first, then is followed by the allantois and yolk sac. The young were presented either head- or body-loop first, and most of the young snakes broke the amnion sac during the process of birth or moments thereafter. The time required for parturition ranged from 1.5 to 2.5 minutes, with a lapse of four minutes to one hour between births. There was no indication of maternal concern for the newborn, which were capable of frolicking and swimming within seconds after birth. These movements effect elimination of the umbilicus cord a short time after birth. All newborn snakes shed their fetal (very thin) skin within 24 hours following birth, and a thicker skin is shed four days later. The sex of the young snakes was determined by pressure-eversion of the hemipenes. New-born weights varied from 2.400 to 4.216 gms (mean = 3.279), whereas total lengths ranged from 172 to 265 mm (mean = 227).

Growth rates were highest during the first year, with yearlings showing an average increase of 75% length increase over newborn. The percentage increase for the second year class averaged 44.8. No definite third year class was distinguishable, so annual growth estimates at that level were not possible. However, the total growth was about 14 to 15% for the older specimens, regardless of age. Summer growth rate, as determined by marking experiments, was approximately 2.5 mm per week. Female queen snakes grow faster than males and they attain larger sizes.

Cloacal temperatures in the queen snake were found to be higher by as much as 6.2° C than ambient temperatures, indicating a tendency to temperature regulation. The highest recorded body temperature was 30.4° C, and the lowest 12.2°. The mean cloacal temperature for all snakes was 25.6° C, which must be considered in light of prevailing ambient temperatures. The critical thermal maxima for adult queen snakes varied from 43.4° C to 44.5° (mean = 43.9), whereas that of juveniles ranged from 39.5° to 41.5° (mean = 40.3), indicating that larger snakes have a higher temperature tolerance than juveniles. Body size apparently does not affect the CTM of adults, but in juveniles it appears to be proportional to body weight and length.

Population size was calculated to be 35 per 210 yards at Otter Creek, and 62 per 259 yards at another point on the same creek. Home ranges are relatively small, although definite sizes were not determined. Homing tendencies were indicated in two examples, although translocated specimens were never recaptured.

Hibernacula were not observed. The first spring-appearance date in Kentucky queen snakes was April 5, and the fall-disappearance date was November 15. No prehibernation aggregations occurred.

Adult queen snakes are subject to predation by crayfish and mice during hibernation, and by other snakes during the active season. Juveniles were observed being preyed upon by crayfish, and young snakes were found in the gut of the hellbender, *Cryptobranchus alleganiensis*.

Two ectoparasites were found on the queen snake: a fungus of the genus *Verticellium*, and a leech, *Placobdella rugosa*.

## Literature Cited


Adler, K. K., and S. G. Tilley. 1960. A fish and a snail in the diet of *Natrix septemvittata*. J. Ohio Herp. Soc. 2:28–29.

Anderson, P. 1965. *Reptiles of Missouri*. U. Missouri Press, Columbia, 330 p.

Barbour, R. W. 1968. Non-venomous snakes of Kentucky. *Happy Hunting Ground*, back cover.

Blanchard, F. N., and E. B. Finster. 1933. A method of marking living snakes for future recognition, with a discussion of some problems and results. Ecology 14:334–347.

Brattstrom, B. H., and P. Lawrence. 1962. The rate of thermal acclimation in anuran amphibians. Physiol. Zool. 35:148–156.

Burghardt, G. M. 1968. Chemical preference studies on newborn snakes of three sympatric species of *Natrix*. Copeia 1968:732–737.

Clark, H., B. Florio and R. Hurowitz. 1955. Embryonic growth of *Thamnophis s. sirtalis* in relation to fertilization date and placental function. Copeia 1965:9–13.

Conant, R. 1938a. The reptiles of Ohio. Amer. Midl. Nat. 20:1–200.

———. 1938b. On the seasonal occurrence of reptiles in Lucas County, Ohio. Herpetologica 1:137–144.

———. 1958. *A field guide to reptiles and amphibians*. Houghton-Mifflin Co., Boston, Mass., 366 p.

———. 1960. The queen snake, *Natrix septemvittata*, in the Interior Highlands of Arkansas and Missouri, with comments upon similar disjunct distributions. Proc. Acad. Nat. Sci. Philadelphia 112:25–40.

Dunn, E. R. 1915. Number of young produced by certain snakes. Copeia No. 22:37.

Funkhouser, W. D. 1925. *Wildlife in Kentucky*. Ky. Geol. Surv., Frankfort, Ky., 385 p.

Green, B. N. 1937. The amphibians and reptiles of Randolph County, West Virginia. Herpetologica 1:113–116.

Hall, R. J. 1969. Ecological observations on Graham's water snake, *Regina grahami* (Baird and Girard). Amer. Midl. Nat. 81:156–163.

Holl, F. J., and L. N. Allison. 1935. *Zeugorchis natris* N. Sp., a trematode from the water snake. J. Parasit. 21:197–199.

Hudson, R. G. 1954. An annotated list of the reptiles and amphibians of the Unami Valley, Pennsylvania. Herpetologica 10:67–72.

Huheey, J. E., and A. Stupka. 1967. *Amphibians and reptiles of the Great Smoky*

*Mountains National Park.* U. Tennessee Press, Knoxville, 98 p.
HUTCHISON, V. H. 1961. Critical thermal maxima in salamanders. Physiol. Zool. 34: 93–125.
HUTCHISON, V. H., A. VINEGAR and R. J. KOSH. 1966. Critical thermal maxima in turtles. Herpetologica 22:32–41.
KENDEIGH, S. C. 1961. *Animal ecology.* Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 468 p.
LOWE, C. H., and J. VANCE. 1955. Acclimation of the critical thermal maxima of the reptile, *Urosaurus ornatus.* Sci. 122:73–74.
LUETH, F. X. 1941. Effects of temperature on snakes. Copeia 1941:125–132.
McCAULEY, R. H. 1945. *The reptiles of Maryland and the District of Columbia.* Pub. by author, Hagerstown, Maryland, 194 p.
MINTON, S. A. 1944. Introduction to the study of the reptiles of Indiana. Amer. Midl. Nat. 32:438–477.
NAKAMURA, E. L., and H. M. SMITH. 1960. A comparative study of selected characters in certain American species of water snakes. Trans. Kansas Acad. Sci. 63:102–113.
NEILL, W. T. 1948. Hibernation of amphibian and reptiles in Richmond Co., Georgia. Herpetologica 4:107–114.
PENN, G. H. 1950. Utilization of crayfishes by cold-blooded vertebrates in the eastern United States. Amer. Midl. Nat. 44:643–658.
POPE, C. H. 1944. *Amphibians and reptiles of the Chicago area.* Chi. Nat. Hist. Mus. Press, Chicago, 275 p.
RANEY, E. C., and R. M. ROECKER. 1947. Food and growth of two species of water snakes from western New York. Copeia 1947:171–174.
SMITH, P. W. 1961. The amphibians and reptiles of Illinois. Ill. Nat. Hist. Surv. Bull. 28:1–298.
SWANSON, P. L. 1952. The reptiles of Venango Co., Pennsylvania. Amer. Midl. Nat. 47: 161–182.
TINKLE, D. W. 1962. Reproduction potential and cycle in female *Crotalus atrox* from northwestern Texas. Copeia 1962:305–313.
TRIPLEHORN, C. A. 1949. A large specimen and high embryo count for the queen snake. Copeia 1949:76.
WEED, A. C. 1922. Reptile notes. Copeia 1922:84–87.
WELTER, W. A., and K. CARR. 1939. Amphibians and reptiles of northeastern Kentucky. Copeia 1939:128–130.
WOOD, J. T. 1944. Fall aggregation of the queen snake. Copeia 1944:253.
———. 1949. Observations on *Natrix septemvittata* (Say) in southwestern Ohio. Amer. Midl. Nat. 42:744–750.
WOOD, J. T., and W. E. DUELLMAN. 1950. Size and scutellation in *Natrix septemvittata* (Say) in southwestern Ohio. Amer. Midl. Nat. 43:173–178.
WRIGHT, A. H., and A. A. WRIGHT. 1957. *Handbook of snakes of the United States and Canada,* Vol. I. Comstock Pub. Assoc., Cornell U. Press, Ithaca, N. Y., 564 p.
ZWEIFEL, R. G. 1957. Studies on the critical thermal maxima of salamanders. Ecology 38:64–69.

January 24, 1974